

# The alien vascular flora of Stromboli and Vulcano (Aeolian Islands, Italy)

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## Abstract

The updated censuses of the alien flora of the islands of Stromboli and Vulcano, Aeolian Islands in the Central Tyrrhenian Sea, are presented here. They currently consist of 40 and 57 specific and subspecific taxa respectively. As many as 16 and 18 taxa respectively are new in comparison with the last censuses in 2016. *Mesembryanthemum × vascosilvae*, commonly cultivated in both islands, is reported for the first time as naturalized alien to Italy. *Passiflora incarnata* from Stromboli and *Pelargonium graveolens* from Vulcano are reported for the first time as casual aliens to Sicily. The evolution over time of these florulas, as inferred from the main floristic works published on these islands, is commented on. Biology, ecology and possible causes of settlement of these plants are discussed briefly.

## Keywords

New records, *Mesembryanthemum × vascosilvae*, *Passiflora incarnata*, *Pelargonium graveolens*, Xenophytes

## Introduction

The key distinguishing factor between native and alien taxa is whether their presence in a region is due directly or indirectly to human activities (Pyšek and Richardson 2006).

Alien species, and in particular invasive ones, are arousing particular interest in the scientific community because they are considered one of the greatest dangers to biodiversity and an effective cost to communities (Vitousek 1990; Chornesky and Randall 2003). Much study has been conducted to adopt standardized definitions in order to

be able to easily compare data from different areas and from different contributions (Pyšek et al. 2004). The study of alien species is also interesting for the elaboration of new theoretical insights on evolutionary and ecological processes (Davis 2006), but in many cases the dates of arrival of new taxa in a territory are not known especially when it comes to territories without precise geographical limits. For small islands this verification is simpler. They have been defined as open-air laboratories for the study of biodiversity (Russell and Kueffer 2019). In islands there is a clear geographical delimitation and they are among the best known territories from the floristic point of view (e.g. Raimondo et al. 2005a; Domina and Mazzola 2011).

In this study we wanted to provide an updated account of the alien vascular floras found on the islands of Stromboli and Vulcano in the archipelago of the Aeolian Islands (Italy). These two islands have a clearly visible volcanic activity and attract every year a high tourist flow for their naturalistic and landscape interest.

The floras of the Aeolian islands have been systematically studied since the first half of the 19<sup>th</sup> century. Giovanni Gussone has visited all the circumsicilian archipelagos and reports in the *Prodromus* (Gussone 1827–1834) and in the *Synopsis* (Gussone 1842–1845) of Flora Sicula numerous plants collected or observed in all the seven main Aeolian islands. Michele Lojacono-Pojero was sent in 1878 to collect plants for the Botanical Garden of Palermo; the list of plants collected were published in a conspicuous contribution (Lojacono-Pojero 1878). Giuseppe Zodda also presents an account of the new plants observed during his visit to the archipelago (Zodda 1904) but for the alien flora of Stromboli and Vulcano he cites only *Solanum lycopersicum* L. Complete studies of the flora and vegetation of the islands of Stromboli and Vulcano date back to about 50 years ago (Ferro and Furnari 1968a, b, 1970). These studies are mainly focused on native flora and only consider the most evident elements of the alien flora. Subsequently, several contributions have been published on single alien taxa of the vascular flora of the Aeolian Islands (Troia 1998; Pasta 2003; Domina 2005; Domina and Spallino 2007; Pasta et al. 2008; Crisafulli et al. 2011; Ardenghi and Cauzzi 2015). Domina and Mazzola (2008) presented a cultivated flora of the circumsicilian archipelagos indicating the naturalized plants. Celesti-Grapow et al. (2016) presented an elaboration on the alien flora of the main Italian islands, but without providing the floristic lists. A complete and updated study of the flora of the Aeolian Islands has been announced several times. It is well known that Professor Gioachino Ferro from Catania has dedicated a large part of his life to the study of the flora and vegetation of this archipelago and had the synthesis of his studies in an advanced stage of preparation, but his disappearance has put a halt. In recent years, the elaborations of data on the flora of this archipelago have been presented (Pasta and La Mantia 2013; Zannini et al. 2018; Pasta et al. 2019; Chiarucci et al. 2021) but the floristic lists are still unpublished.

Hence the need to prepare this summary that gives a knowledge base for the administrators and managers of these areas who need the most complete and updated data to be able to make informed choices for the conscious management of greenery in the anthropized and semi-natural environments of these territories.

## Material and methods

### Characteristics of the two islands

Stromboli is the northernmost island of the Aeolian Islands and the most distant from the mainland (55 km). It covers an area of 12.2 km<sup>2</sup>, with an elevation of 926 m a.s.l. It hosts the homonymous volcano, considered one of the most active in the world. There are two main residential areas, San Vincenzo and Piscità on the north-eastern side, and the village of Ginostra on the western side. The main activities of its inhabitants, until the 70s of the 20<sup>th</sup> century, were agriculture and fishing. Currently the main source of livelihood is tourism. In 1971, before the tourist boom, there were 400 residents, today there are 639 (Di Chiara et al. 2015; <https://italia.indettaglio.it>). No noticeable increase in buildings has been recorded on Stromboli after the tourist development (Cavallaro and Famularo 1977; Moreno 1995). In August a fluctuating population of about 2,500 people is estimated (Di Chiara et al. 2015).

Vulcano is the southernmost island of the Aeolian archipelago and the closest to the mainland (20 km). It has an area of 20.87 Km<sup>2</sup> and reaches an altitude of 499 m a.s.l. The last eruption of Vulcano occurred in 1890. The volcano is currently considered quiescent and the activity of fumaroles is the most evident one. At present the island's economy is based on tourism. The island of the volcano saw intense industrial activity around the port for the extraction of volcanic products, mainly sulphur and alum until the early 20<sup>th</sup> century. The central part of the island, and the flat surroundings of the port were used for agriculture. Traces of this activity remain in the central part of the island. The surroundings of the port and the Vulcanello peninsula have been affected, since the sixties of the 20<sup>th</sup> century, by intense tourist construction that has heavily modified the landscape of the island (Lo Cascio 2012). There are 715 residents (<https://italia.indettaglio.it>); in August a floating population of about 4,000 people is estimated (Di Chiara et al. 2015).

### Data collection and analysis

Despite the authors have twenty years of knowledge of the islands, the floristic investigation for this contribution was carried out with specific field surveys in various seasons since 2016. The presence and distribution of all alien plant species observed was recorded, assessing the invasive status.

Trivial plants were identified *in situ*; the problematic specimens were collected or photographed and then identified using the reference flora of the territory (Tutin et al. 1964–1980, 1993; Pignatti 1982; Pignatti et al. 2017–2019), the “European garden flora” (Walters et al. 1984, 1986, 1989; Cullen et al. 1995, 1997, 2000), and contributions on single taxa monographies (e.g. Sanders 2006, 2012; Verloove 2008; Ardenghi et al. 2014, 2015; Ardenghi and Cauzzi 2015; Gallo 2019; Smith et al. 2020). New herbarium specimens were housed in the “Herbarium Mediterraneum Panormitanum” (PAL; herbarium acronyms according to Thiers 2021+). The nomenclature follows Galasso et al. (2018), and subsequent updates summarised in the Portal to the Flora of Italy

(<http://dryades.units.it/floritaly/>: see Galasso et al. 2020; Martellos et al. 2020). Data concerning the identified taxa were added in a second stage: family, life form, chorology or origin according to Pignatti et al. (2017–2019), archaeophytic or neophytic status according to Galasso et al. (2018), habitat in which the plant was found, pathways of introduction, main reproductive strategy adopted, Ellenberg's indicator values according to Domina et al. (2018b), and the presences recorded in this study and in the main floristic contributions of the two islands (Gussone 1842–1845; Lojacono-Pojero 1878; Ferro and Furnari 1968a, b, 1970; Domina and Mazzola 2008; Celesti-Grapow et al. 2016) with degree of naturalization according to Galasso et al. (2018). Criptogenetic taxa recorded for the two islands (e.g. *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop., *Oxalis corniculata* L. in Vulcano, *Papaver dubium* L., *P. rhoeas* L. subsp. *rhoeas* in Stromboli, and *Portulaca oleracea* L.) were not included in this account.

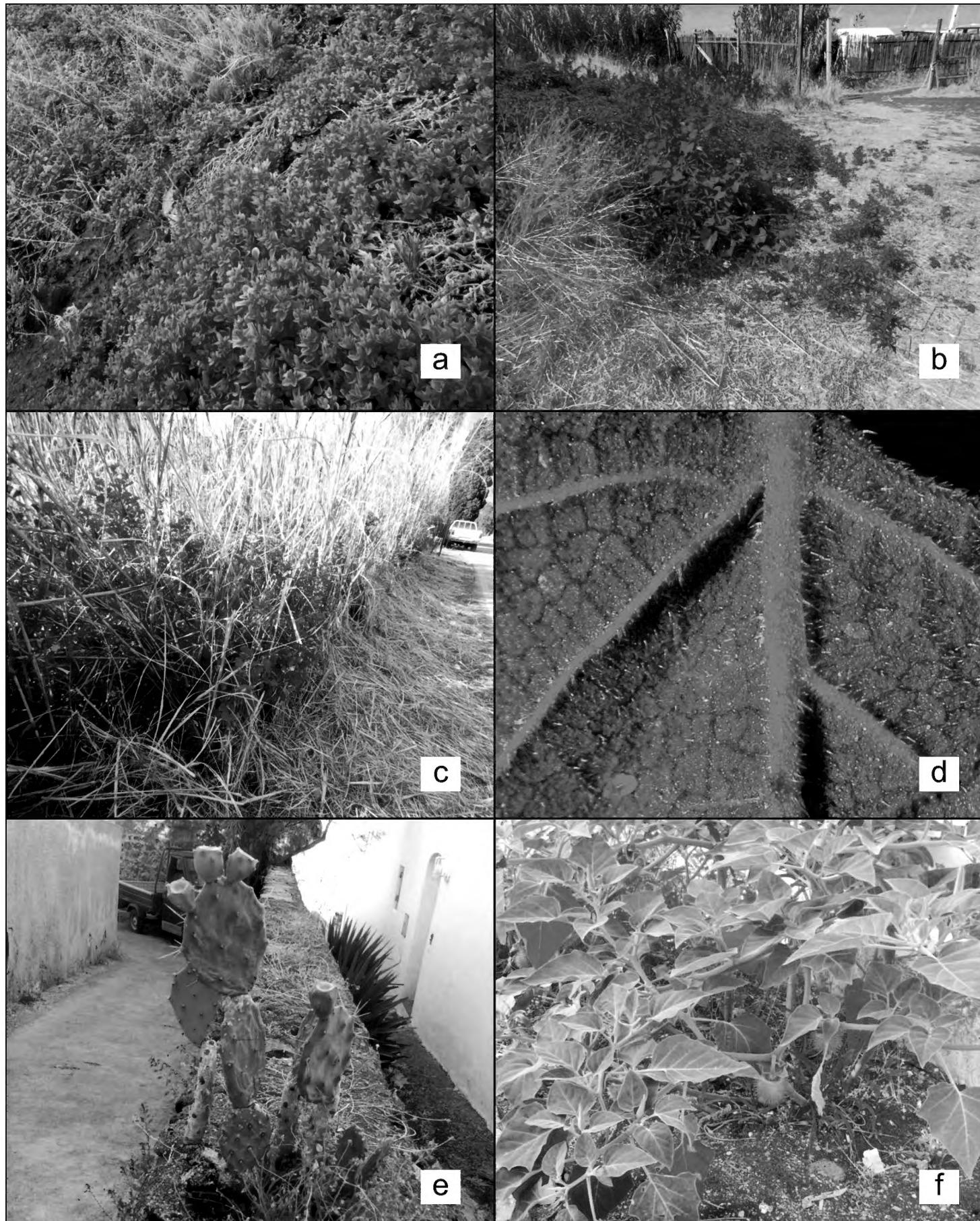
## Results

Alien species were mainly recorded in the altimetric range from sea level to 100 m a.s.l. on Stromboli, on Vulcano from sea level to 50 m a.s.l. around the town of the port and between 300 and 400 m a.s.l. in the centre of the island. More than 80% of the taxa surveyed are neophytes. Inhabited areas are the most prone to host alien species. This is justified by the fact that the large part of these plants was introduced voluntarily as ornamentals. In many cases these aliens have also colonized agricultural areas. In the small islands, where spaces are limited, it is easy to have mixed land uses, finding purely ornamental plants grown alongside vegetable gardens and seeing fruit trees used as ornamental plants.

Overall, 62 alien species and subspecies were found growing wild in the two islands, 40 in Stromboli and 57 in Vulcano. The list includes 6 archaeophytes introduced in Italy before the discovery of Americas, and 56 neophytes. In Stromboli there are 5 casual, 29 naturalized and 6 invasive taxa; in Vulcano 13, 39 and 5 taxa respectively (Table 1 and Suppl. material 1). In comparison with the unpublished data used by Celesti-Grapow et al. (2016), 16 taxa are new to Stromboli and 18 to Vulcano. *Mesembryanthemum × vascosilvae* (Gideon F.Sm., E.Laguna, Verloove & P.P.Ferrer) L.Sáez & Aymerich is naturalized in Stromboli and Vulcano. This is its first report from Italy. Field and herbarium studies are needed throughout the whole territory of Italy to identify the taxa belonging to this group and trace their distribution. *Passiflora incarnata* L. from Stromboli and *Pelargonium graveolens* (Thunb.) L'Hér. from Vulcano are reported for the first time as casual aliens to Sicily (Fig. 1). The former was collected near San Vincenzo in an area of about 50 m<sup>2</sup> with sandy soil, where it produced several young sprouts. The latter has been extensively planted in Vulcano as ornamental along the roads and in various localities (Vulcanello, near the port, at Piano, etc.), from where it has reproduced vegetatively by invading several square meters. It has been shown that the vegetative propagation of alien species in the Mediterranean islands, although does not guarantee long-distance spread, ensures a rapid expansion and maintenance within suitable habitat (Lloret et al. 2005).

**Table I.** Characteristics of the alien flora of Stromboli and Vulcano: life forms, chorology, introduction time, invasiveness, habitat, pathways of introduction, reproductive strategy adopted, means of Ellenberg's indicator values.

| Life form                          | Stromboli |        | Vulcano |        |
|------------------------------------|-----------|--------|---------|--------|
|                                    | no.       | %      | no.     | %      |
| T                                  | 12        | 30.00  | 16      | 28.07  |
| G                                  | 4         | 10.00  | 5       | 8.77   |
| H                                  | 2         | 5.00   | 2       | 3.51   |
| Ch                                 | 5         | 12.50  | 6       | 10.53  |
| NP                                 | 1         | 2.50   | 3       | 5.26   |
| P                                  | 16        | 40.00  | 25      | 43.86  |
| TOT                                | 40        | 100.00 | 57      | 100.00 |
| Chorology                          | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| Africa                             | 6         | 15.00  | 9       | 15.79  |
| America                            | 21        | 52.50  | 24      | 42.11  |
| Australia                          | 3         | 7.50   | 5       | 8.77   |
| Asia                               | 2         | 5.00   | 6       | 10.53  |
| Europe & Mediterranean             | 1         | 2.50   | 3       | 5.26   |
| Wide distribution                  | 4         | 10.00  | 8       | 14.04  |
| Cultigen                           | 3         | 7.50   | 2       | 3.51   |
| TOT                                | 40        | 100.00 | 57      | 100.00 |
| Introduction time                  | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| Archaeophyte                       | 2         | 5.00   | 5       | 8.77   |
| Neophyte                           | 38        | 95.00  | 52      | 91.23  |
| TOT                                | 40        | 100.00 | 57      | 100.00 |
| Invasiveness                       | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| Casual                             | 5         | 12.50  | 13      | 22.81  |
| Naturalized                        | 29        | 72.50  | 39      | 68.42  |
| Invasive                           | 6         | 15.00  | 5       | 8.77   |
| TOT                                | 40        | 100.00 | 57      | 100.00 |
| Habitat                            | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| agricultural                       | 24        |        | 25      |        |
| inhabited                          | 34        |        | 47      |        |
| reforestation                      | 3         |        | 4       |        |
| roads                              | 10        |        | 15      |        |
| rocky outcrops                     | 2         |        | 2       |        |
| beaches and inland sands           | 6         |        | 5       |        |
| Pathway of introduction            | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| unintentional                      | 10        |        | 13      |        |
| agriculture                        | 9         |        | 9       |        |
| forestry                           | 4         |        | 6       |        |
| industry                           | 3         |        | 2       |        |
| ornament                           | 24        |        | 37      |        |
| Reproductive strategy              | Stromboli |        | Vulcano |        |
|                                    | no.       | %      | no.     | %      |
| seed                               | 36        |        | 51      |        |
| vegetative                         | 15        |        | 19      |        |
| Ellenberg's Indicator Values Means | Stromboli |        | Vulcano |        |
|                                    | L         | 8.13   | T       | 8.60   |
| T                                  |           | 8.65   |         | 8.74   |
| K                                  |           | 4.76   |         | 4.69   |
| F                                  |           | 3.80   |         | 3.68   |
| R                                  |           | 5.56   |         | 5.26   |
| N                                  |           | 4.56   |         | 4.07   |
| S                                  |           | 0.15   |         | 0.16   |



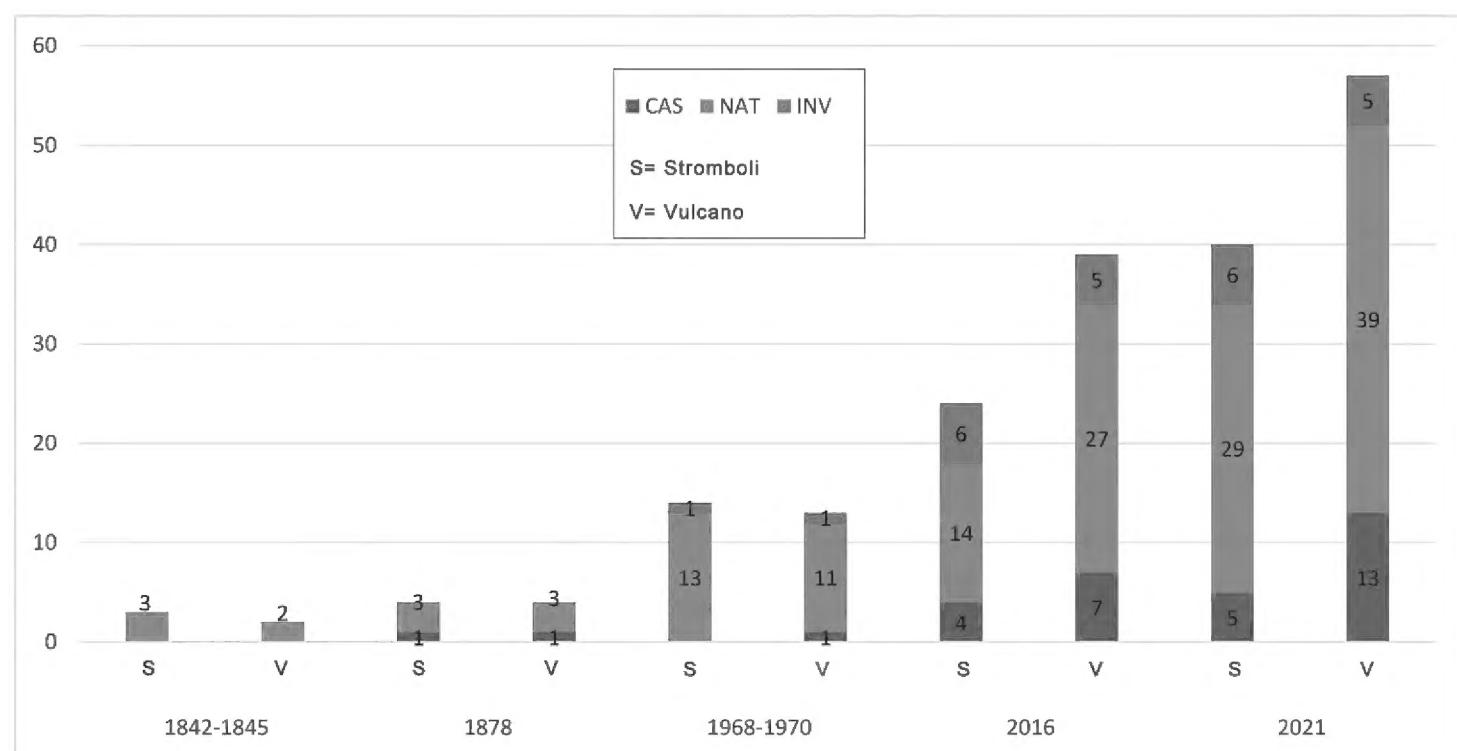
**Figure 1.** **a** *Mesembryanthemum × vascosilvae* naturalized in Stromboli **b** *Passiflora incarnata* on sands in Stromboli near San Vincenzo **c** *Pelargonium graveolens* and *Saccharum biflorum* in Vulcano along the roads **d** abaxial leaf surface of *Lantana camara* subsp. *aculeata* from Stromboli **e** *Opuntia dillenii* on a wall in Stromboli at Piscità **f** *Datura wrightii* grown spontaneously in a flower bed in Vulcano and treated as an ornamental.

The species that have proved to be fearsome invasive occupying large surfaces and showing the ability to modify the environment in which they are located are: *Ailanthus altissima* (Mill.) Swingle, *Arundo donax* L., *Carpobrotus acinaciformis* (L.) L.Bolus in Stromboli, *Oxalis pes-caprae* L., and *Saccharum biflorum* Forssk. (Fig. 1). The latter,

used to build border hedges (Lojacono-Pojero 1878), has now invaded large, uncovered areas previously cultivated or made up of unfixed sand. The two florulas surveyed are similar in their floristic composition and therefore in their biological and chorological characteristics, period of introduction into the national territory, invasion status, habitat, pathways of introduction, reproductive strategy, and ecological requirements (Table 1). The two florulas are dominated by American species alike to the alien flora of the whole of Sicily (Raimondo et al. 2005b). Concerning ecological requirements, the florula of Vulcano has slightly higher light requirements ( $L = 8.60$  vs. 813) and slightly lower preference for higher nutrient availability ( $N = 4.07$  vs. 4.56). Comparing these florulas with the alien flora of Italy (Domina et al. 2018b) they have slightly higher light ( $L = 8.60$  Vulcano and 8.13 Stromboli vs. 7.85), higher temperature ( $T = 8.74$  and 8.65 vs. 7.67), and lower edaphic humidity requirements ( $F = 3.68$  and 3.80 vs. 4.50).

## Discussion

The diachronic comparison of the main floristic checklists of Stromboli and Vulcano allowed us to appreciate the exponential increasing number of alien plants (Fig. 2). This is in part due to the greater attention that scientific research has given to this biological component over time, but in part due to the increasing number of people who spend their holidays on the islands and, consequently, to the increasing number of plants introduced as ornamentals. The presence of stable nurseries and hawkers of plants, in addition to the plants transported by individual homeowners, ensures a constant supply of new taxa. The plain of Milazzo, on the mainland, opposite the Aeolian archipelago is one of the most active nursery centres in Sicily. This is also a general trend as the incidence of such species among invasive taxa is widely recognized to be



**Figure 2.** Alien vascular plants recorded in the main floristic works on the islands of Stromboli and Vulcano (CAS = casual; NAT = naturalized; INV = invasive).

quite high (e.g. Reichard and White 2001; Foxcroft et al. 2008). The same was also recently observed for the island of Linosa, in the Sicilian channel (Pasta et al. 2017), or for Italy as a whole (Bartolucci et al. 2021). The cessation of cultivation would lead to the disappearance of many casual species. The case of *Kleinia madraliscae* Tineo is emblematic, an alien species naturalized on the island at the beginning of the 19<sup>th</sup> century, described as native and considered endemic (Pasta 2003; Domina 2005) but within 50 years since its description, the cultivation fell into disuse and the plant almost disappeared from the island. Today it is only rarely grown in a few spots. More targeted studies on aliens trends should be conducted to verify whether the global climate change is also having appreciable effects on the alien component of the florulas of the small Mediterranean islands. The same applies to ascertaining whether the small islands are per se more subject to invasion by alien species than the mainland or whether the high rates of alien species found are mainly attributable to the strong anthropogenic pressure to which they are subjected in the summer. Besides disturbance, intense propagule pressure, defined as the rate of influx of alien propagules into the target area has been observed to be an important contributor to the establishment of new alien plants (Celesti-Grapow et al. 2010).

## Conclusions

Stromboli and Vulcano, despite having similar biological, environmental and climatic conditions, so that they are classified in the same synthetic cartography subunit (Domina et al. 2018c) host a different number of endemic taxa. According to Domina et al. (2018a), Vulcano is richer than Stromboli. This despite the fact that the quality of the habitats on Vulcano has deteriorated considerably in the last century. Based on the results presented here, Stromboli and above all Vulcano appear to be particularly prone to invasion by aliens, probably due to substantial introductions for ornamental and horticultural purposes, but also to the availability of nutrient and water rich sites as orchards and surroundings of the houses. The abandonment of agriculture in large areas of the islands may be a factor that has favoured the spread of alien species (Pretto et al. 2010).

The data here presented underline the need of integrated policies for a more conscious use of the territory. This approach should promote the use of traditional agriculture, cultivation techniques and traditional cultivars of agricultural and ornamental plants rather than the embellishment of temporary vacation places with species spread throughout the globe. All this to aim at an environmental restoration, characterizing the landscape while making it pleasant and unique in the eyes of the residents and of the visitors.

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## Supplementary material I

### Table with the species and subspecies of alien vascular plants present in the islands of Stromboli and Vulcano

Authors: Di Gristina E, Domina G, Barone G

Data type: occurrences and biological data

Explanation note: The following data are included: family; life form (according to Pignatti et al. 2017–2019); chorology; time of introduction in Italy (cryptogenetic, archaeophyte, neophyte) ; the habitats where the plants have been recorded (agr: agricultural, inh: inhabited, ref: reforestation, roa: road, roc: rocky); means of introduction (none, agric: agricultural; forest: reafforestation, ind: industrial, orn: ornamental); reproductive strategy observed (seed, vegetative); Ellenberg's Indicator Values (according to Domina & al. 2018) and the occurrence in the two islands with the invasion status (CAS: casual, NAT: naturalized, INV: invasive).

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